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"Some remarks on the distribution of zooplankton, fish eggs and larvae in the Norwegian Sea in 1958!!

Investigations carried out by the Institute of Marine Research, Bergen, Norway.

By

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During the year 1958 vertical Nansen net ("8/70") hauls from bottom to surface and 50 to 0 m, were taken regularly at the permanent hydrographical stations along the coast of Norway and Spitsbergen (Sognesjøen, Skrova, Skarsvåg, Kongsfjord (Kings Bay)), and during the first half of the year at the weathership station "M" (Fig. 1). At station "M" half hour's horizontal hauls were also taken weekly with a one metre net at the surface.

During the cruise of R/S "Johan Hjort" in the Norwegian Sea and the northern North Sea, from 28. April to 24. June, vertical hauls 100 to 0 m were taken with a one metre egg net (mesh size 0.5 mm) on 229 stations, and horizontal hauls with a high speed net on 43 stations (Fig. 2). The high speed net, a Gulf III model (Gehringer 1952) without nose-piece and current meter, was towed for 25 minutes at a speed of 8 knots in steps with varying wire length (125 - 25 m wire).

I. Zooplankton.

The variations in volume of the zooplankton during 1958 at the permanent hydrographical stations and at station "M".

At Sognesjøen plankton was sampled in March, April, September, October and December. During these months the plankton was very sparse with a maximum mean value of 2.5 ml per haul in April.

A single Salpa fusiformis was taken in the middle of September.

At Skrova plankton was collected frequently throughout the year. Fig. 3 is based on the monthly means. The winter minimum occurs in March. There are peaks in May and July. The plankton was on the whole more abundant than in 1957, especially in the upper layers, the spring and summer maxima being more pronounced and occurring earlier in 1958.

As in 1955, large numbers of Salpa fusiformis were taken throughout October.

At Skarsvåg plankton was sampled from the end of June to November (Fig. 4). As in 1957 there were peaks in July and September but the plankton was more abundant than in the previous year.

At Kongsfjord (Kings Bay) a fairly representative material was collected from April to September (Fig. 5). The volume curve has a minimum in February, and two peaks, one smaller in June, and a main peak in August. During the last half of September there was also some increase. In the upper 50 m peaks occurred both in July and August, and the September increase is more pronounced. The plankton was richer than in the previous year, and, as usual, Calanus finmarchicus constituted the bulk of the plankton.

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At station "M" plankton was sampled from January to the end of June. During the last half of the year the Norwegian weatherships were stationed at st. "A" in the Denmark Strait. The plankton material collected at "A", has been handed over to the Danish Plankton laboratory.

In the table below are given the monthly mean volumes in the upper 600 m at st. "M" (in ml):

Haul	Jan.	Febr.	March	April	May	June
25 - 0 m	<0,5	<0,5	0,5	0,7	2,4	2,0
100 - 0 m	<0,5	<0,5	1,3	1,7	4,1	2,7
600 - 100 m	3,5	0,5	5,5	-	4,0	7,0

As in previous years, a maximum in volume in the upper 100 m was observed in May, but the plankton was less abundant than in 1957. In daytime the horizontal surface hauls yielded small quantities of plankton, except for one haul of 180 ml at the end of May. The night hauls were richer, with a maximum mean value of 127 ml in April. No night hauls were taken in January and March.

The quantitative distribution of zooplankton in the Norwegian Sea during May-June 1958 compared with simultaneous echo recordings.

The plankton material collected in May-June 1958 during the cruise of R/S "Johan Hjort" in the Norwegian Sea can only give a rough picture of the quantitative distribution (Fig. 6), as various errors are involved in the sampling, one of the major ones being the variation in plankton volume between day and night hauls. In the northwestern cold area the plankton was fairly abundant, mainly consisting of Calanus hyperboreus. In the central area the plankton was sparser, but the Norwegian coastal and bank areas were again richer. The dominating species was Calanus finmarchicus, but in some places euphausiids (krill), fish fry, and medusae played an important part. As was to be expected, the largest quantities of plankton were taken during night time. When echo sounders are operated in coastal or oceanic areas, a shallow scattering layer, giving diffused echoes, may be recorded continuously for hundreds of miles, especially during the spring-autumn period. The recordings may vary both with respect to intensity and depth, but are usually limited to the upper 30-50 metres. Such a scattering layer has sometimes been identified as echoes of small fish, but the operators are of the opinion that the usual zooplankton organisms, copepods, euphausiids and others may also be important as sound scatterers.

In order to investigate if echo sounders can give a quantitative picture of the horizontal distribution of zooplankton, a special SIMRAD machine, producing signals of 27 kc, was run continuously during the whole cruise of the "Johan Hjort". Each half-hour the operator noted the average vertical extent of the recordings (e.g. 10-50 m, 5-25 m) and made estimates of the intensity on a subjective scale from 1 to 6. The chart which was prepared from these recordings (Fig. 7) does not agree very well with the quantitative distribution of plankton as revealed by the volume measurements (Fig. 6). Particularly in the northwestern area, where the echo survey was entirely negative, no agreement is found.

The borders of zero recording nearly follow the 3° - 4° isotherms at the 20 m level. In the central area, there is a certain agreement between small plankton volumes and echo recordings of low intensity, but in the eastern part the maximum of recordings does not coincide with the area of maximum plankton volumes.

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It thus seems, as if the echo sounder used cannot give a reliable picture of the quantitative distribution of the zooplankton. According to Fraser (1957), Calanus finmarchicus and salps are ineffective as sound reflectors for the echo sounders used on board the Scottish research ship "Scotia".

In order to find out which organisms were possibly responsible of the echo recordings, all the species present in the plankton samples were listed. Five groups of organisms were selected because of their size, namely appendicularians, chaetognaths, krill, fish fry and medusae. The chaetognaths occurred on nearly all stations, and no correlation could therefore be found with the echo recordings. In the remaining four groups the following relations were found:

In the areas without any recording:

No. of stations without recording	No. of stations with catches of: Appendicularians	Krill	Fish Fry	Medusae	Nil
68	4	25+)	2+)	0	40

+) Single specimens only.

In the areas with recording of "plankton":

No. of stations with recording	No. of stations with catches of: Appendicularians	Krill	Fish Fry	Medusae	Nil
157	65	111	85	41	5

Krill, fish fry and medusae did not occur in the "negative" area, except as single specimens. In the "positive" area only 20 of the stations yielded merely appendicularians and/or medusae. On the remaining stations krill and fish fry were also present.

In the areas with maximum of echo recordings krill and fish fry were taken on all stations, partly in large numbers.

It seems as if the recording of "plankton" may in general be referred to the organisms mentioned above, chiefly krill and fish fry. In a few cases small squid have been caught, and it is likely that they also play a certain part as sound scatterers. Usually very few squids are caught in the plankton nets, and the operators are of the opinion that the echoes caused by squid may be distinguished from other echo signals.

The horizontal distribution of the various copepodite stages of Calanus finmarchicus.

The plankton nets used were of silk No. 0 (mesh size 0.5 mm), therefore nauplii and the copepodite stages I of Calanus finmarchicus were not caught in quantitative numbers (Wiborg 1948). It may nevertheless be of some interest to compare the stage distribution of Calanus finmarchicus in the various areas. According to Pavstikhs (1956) the biological spring occurs at different times in the various parts of the Norwegian Sea, in March-April along the western and northwestern coasts of Norway, in May-June in the central area, and in July-August in the western and northwestern areas.

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The average stage distribution of Calanus finmarchicus is shown in Fig. 8. In the southeastern area the spring spawning was probably completed before the cruise started, and the copepodite stages III-IV present belonged to the spring generation. At some distance from the coast there is a wedge with predominance of the stages V-VI, evidently related to warmer water of the North Atlantic current (Fig. 9). Different wedgeshaped areas with predominance of stages IV-V (4.0 - 4.5) can be followed northwards.

As the observations were made during a period of more than $1\frac{1}{2}$ month, the material does not justify a very detailed synoptic description. The isopleths usually follow the isotherms quite closely at the 20 m level (Fig. 9), and the attention is drawn to the isopleths in the sections from Bear Island to the west and south, and to the tongue of stages V-VI (5.5) running north and northeast at approximately 5° W.

The stage distribution of Calanus finmarchicus may thus be used supplementary to the hydrographical observations in order to distinguish the various water masses in the Norwegian Sea.

II. Fish eggs and larvae.

The plankton material collected at the Skrova station (Fig. 1) since 1949 has proved very useful in the study of the spawning and development of eggs and larvae of the arcto-Norwegian stock of cod (skrei) in this area (Wiborg 1957). The variation in number of cod eggs and larvae at Skrova during 1958 is shown in Fig. 10. In February a few eggs were present, in March the number increased to a maximum of more than 1200 per haul, and decreased throughout the following two months to zero at the end of May. The cod larvae appeared at the beginning of April with greatest abundance at the end of this month and in the middle of May. Later in the season the larvae probably avoided the Nansen net. Cod eggs and larvae were much more abundant than in 1957.

The size distribution of cod eggs in various years has been studied at Skrova (Fig. 11). A small, but obvious decrease in the mean size from the beginning to the end of each season was observed, especially in 1951 and 1957, but rather inconspicious in 1956. The variations in egg size are assumed to be related to the size of the fish. In some fishes, e.g. the char (Salvelinus alpinus) the larger females produce larger eggs than the smaller ones (Aass 1951). It is generally known that in the Lofoten area the larger skrei usually arrive first at the spawning places, and the smaller fish at the end of the season (Sund 1938).

A similar variation in the mean size has also been observed in haddock eggs at the weathership station "M" in the Norwegian Sea. In 1958 some eggs of haddock were taken at station "M" from 11. April to 13. May, mainly in surface hauls with a one metre net. The size distribution of 84 eggs sampled 25. April is given below:

55	56	57	58	59	60	61	62	eye-piece units
3	3	11	11	23	16	10	3	

Mean size 58.9 un. = 1.47 mm.

In 1954 the mean size was nearly the same (58.8 un.) and well above that of 1955 (56.8 un. = 1.42 mm) and 1956 (57.3 un. = 1.43 mm).

Newly spawned eggs of cod and haddock are very difficult to distinguish, and differences in the size distributions of the eggs have been used with some success (Saville 1956). However, such differences should be used with care, as annual or seasonal variations in egg size within the same species, such as those referred to above might invalidate the method.

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The cruise of the "Johan Hjort" to the Norwegian Sea was not planned specially for investigation of fish eggs and larvae. The observations in coastal waters are few and the dispersal in time is great, nearly two months. The material has, nevertheless, given much valuable information on the distribution of eggs and larvae of various species of commercial fish.

Cod. (Fig. 12). At the end of May vertical hauls yielded cod larvae on some of the stations off Lofoten and Vesterålen with a maximum of 27 specimens per haul, and a few larvae on the banks farther northeast. In the period 17.-24. June some cod fry, 10 to 30 mm in length, were taken in the same area with a high speed net (Table 1).

Table 1. Number and length distribution of cod fry taken in high speed net (125-25 m wire length), 25 minutes, speed 8 knots 17.-24. June 1958 off northwestern and northern Norway.

Area	No. per station	Length, mm						Mean length
		8-12	13-17	18-22	23-27	28-32	33-37	
Tromsø-flaket-North Cape	18	-	11	17	8	-	-	19.8
Andenes-Eggum	55	2	25	53	24	6	1	20.4
Off Eggum	32	2	12	46	54	38	10	24.5

It is noticed that the largest cod fry taken, off Eggum, had a mean length of 24.5 mm.

Haddock. (Fig. 13). Eggs and larvae of haddock occurred in two main areas. On the Viking Bank and east of Shetland, up to 75 eggs and 11 larvae per vertical haul were taken at the end of April. A few larvae and eggs were caught on the Halten Bank and along the edge of the continental shelf. The other main area was situated off Vesterålen. Single haddock larvae were taken in the open ocean very far off shore. This conforms with the occurrence of haddock eggs in the same area in earlier years.-

Most of the larvae measured 5-11 mm, single specimens as much as 18 mm. During the last half of June small haddock, measuring 26-46 mm, in length, were caught in the high speed net off Vesterålen.

According to earlier Russian and Norwegian investigations, the spawning areaof the Barents Sea haddock is situated along the edge of the continental shelf from Sørøy to 65° N., with the centre off Andenes and Vesterålen. The eggs and larvae may remain for some time in the anti-clockwise eddies situated off the edge, but are gradually transported north- and northeastwards. In July-August the young haddock are dispersed over a wide area, but mainly north of 70° N.

Saithe. (Fig. 14). A few eggs and larvae of saithe were taken at the end of April east of the Viking Bank, and in the first half of May off Stadt and on the Halten Bank. In June single young saithe, 17-45 mm of length, were caught with the high speed net on the coastal banks between Sørøy and Lofoten.

Tusk. (Fig. 15). Eggs of tusk were mainly found within the 400 m contour with a maximum of 15 eggs per vertical haul (20 pr m^2). In May, single newly hatched larvae were taken on the Halten Bank. According to earlier investigations the tusk also spawn in the deep of the Norwgian fjords.

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Herring. (Fig. 16). At the end of April, herring larvae were numerous on two stations northeast of Shetland. The length distribution was as follows:

9	10	11	12	13	14	15	16	17	18	mm	Mean length
1	1	8	6	15	14	15	6	1	2		13.7 mm

At the beginning of May herring larvae were also taken off Stadt and near the Halten Bank, with a maximum of 28 specimens per haul. The mean length of the larvae decreased from 19 mm to 12 mm in a section from the bank towards the coast.

Only single herring larvae were caught on the banks northeast of Vesterålen, and observations are assumed to be taken too late in the season to trace the spawning in this area.

From the end of May to the last half of June fairly large numbers of herring fry were caught in the high speed net (Table 2).

Table 2. Number and length distribution of herring fry taken with high speed net (125-25 m wire length, 25 minutes, speed 8 knots) in various areas along the Norwegian coast 31. May - 6. June and 17. -24. June 1958. (See Fig. 15).

Area	Length in mm								Mean length mm	Average no. per station
	13-17	18-22	23-27	28-32	33-37	38-42	43-47	48-52		
Off Lofoten-Vesterålen 31. V-6. VI	2	18	38	15	1	-	-	-	25.2	12
(Bear Isl.)-Fugløy-N. Cape	-	24	112	18	2	-	-	-	25.2	25
N. Cape-Lofoten	8	46	95	36	2	-	-	-	24.4	31
Lofoten-Møre	-	15	93	54	10	2	-	-	27.0	17
St. 445	-	-	-	-	1	12	16	4	43.4	

With the exception of one sample (st. 445) the herring usually varied in length from 13 mm to 42 mm, and the mean lengths from 24.4 mm to 27.0 mm. The smaller larvae were taken close to the coast, the larger ones farther out at sea.

One haul taken at the edge (Fig. 16, st. 445) yielded herring fry 37-49 mm of length, mean size 43.4 mm. These herring may have originated from an earlier spawning than the bulk of the fry taken, either off Møre, or they have drifted with the currents from the Faroe area. The herring fry taken off Møre on 24. June, were however, much smaller, with a mean length of 25.6 mm.

Redfish. (Fig. 17). Fry of redfish were chiefly taken in the vertical hauls between the edge of the continental shelf and the central part of the Norwegian Sea. The boundary of the distribution towards the west agrees very well with the 4° C isotherms at the 20 m level. (Fig. 9), and also with the limits given by Baranenkova et. al. (1957). Off Andenes redfish larvae numbered up to 137 per haul, and the larvae were also numerous farther north, outside the 1000 m contour. At all stations the length distribution was quite ./.

narrow, from 7 to 13 mm with a mean length of 9.4 mm. Most of the larvae measured 8-11 mm.

In the middle of June redfish fry were numerous in the high speed net hauls between Bear Island and North Cape, with the following length distribution:

7	8	9	10	11	12	13	14	15	mm	Mean length
1	1	8	25	51	55	33	12	5		11.7 mm

A few larvae caught simultaneously in vertical hauls with a one metre net measured 9-12 mm, mean length 10.2 mm. West of Bear Island three small redfish, measuring 12, 24 and 27 mm respectively, were caught on 13. June.

For a study of the growth of the redfish it might be of interest to compare these data with the length distribution of small redfish taken from the stomachs of cod and haddock of the 0-group, caught with purse seine 30. July 1957, 120 n. miles to the northwest of Andenes:

7	8	9	10	11	12	13	14	15	16	17	18	19	mm	Mean length
1	2	4	10	11	17	8	4	3	2	1	1	1		11.9 mm

At Syltefjord on the Varanger peninsula, North Norway, some young redfish were taken with the high speed net 4. August 1955. They measured as follows:

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	mm
1	0	0	1	3	3	3	5	5	2	2	2	1	3	0	1	

Mean length 19.8 mm

Tåning (1949) gives a mean length of 12-14 mm of redfish fry taken in the North-Atlantic in June-July.

Summary.

During 1958, zooplankton was collected at 4 permanent stations along the Norwegian and Spitsbergen coasts, and at the weathership station "M" (Fig. 1). Peaks in plankton volume occurred in May and July at Skrova, in July and September at Skarsvåg and at Kongsfjord, Spitsbergen. The plankton was more abundant than in the previous year, except at station "M".

Salps occurred at Sognesjøen in September, and at Skrova and Skarsvåg in October.

The spawning of cod has been followed at Skrova during the spring of 1958. - The peak of spawning occurred in the middle of March.

There appears to be a general decrease in the mean egg size during the spawning season in the various years, correlated with the size of the fish. The same feature has been observed in haddock eggs from station "M".

Zooplankton and fish fry were sampled during a cruise in the Norwegian Sea in April-June 1958. An echo sounder was run continuously during the cruise in order to record the zooplankton. The records did not agree with the quantitative distribution of plankton and the sound scattering is assumed to be caused mainly by euphausiids, fish fry, small squid and medusae.

Cod larvae were mainly found in the Lofoten-Vesterålen area.

Eggs and larvae of haddock occurred on the Viking Bank, the Halten Bank and off the edge outside Lofoten and Vesterålen. The latter area is supposed to be the main spawning area of the Barents Sea haddock. ./.

Saithe larvae and eggs were taken on the Viking Bank and Halten Bank, larger fry farther north.

Tusk eggs occurred mainly within the 400 m contour from the Northern North Sea to Vesterålen.

Herring larvae were plentiful in April-May east of Shetland and on the Halten Bank. Larger herring fry were taken in June with the high speed net in the coastal areas from Northcape to Møre.

Redfish larvae were numerous in the Lofoten-Andenes area, mainly off the edge. Larger fry were taken in June in the section Bear Island-Fugløy.

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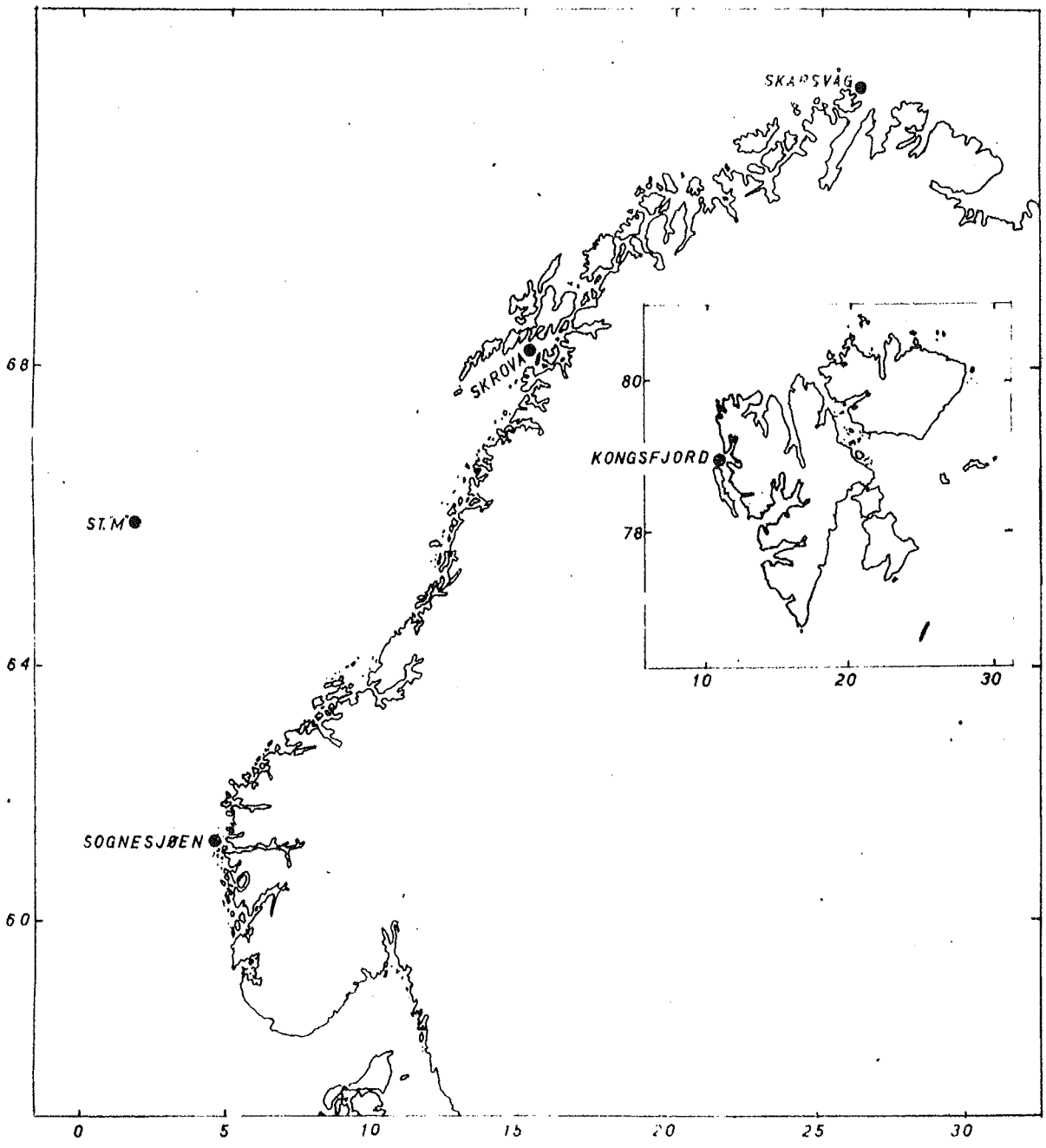

Fig. 1. Permanent zooplankton stations in Norwegian and Spitsbergen waters.

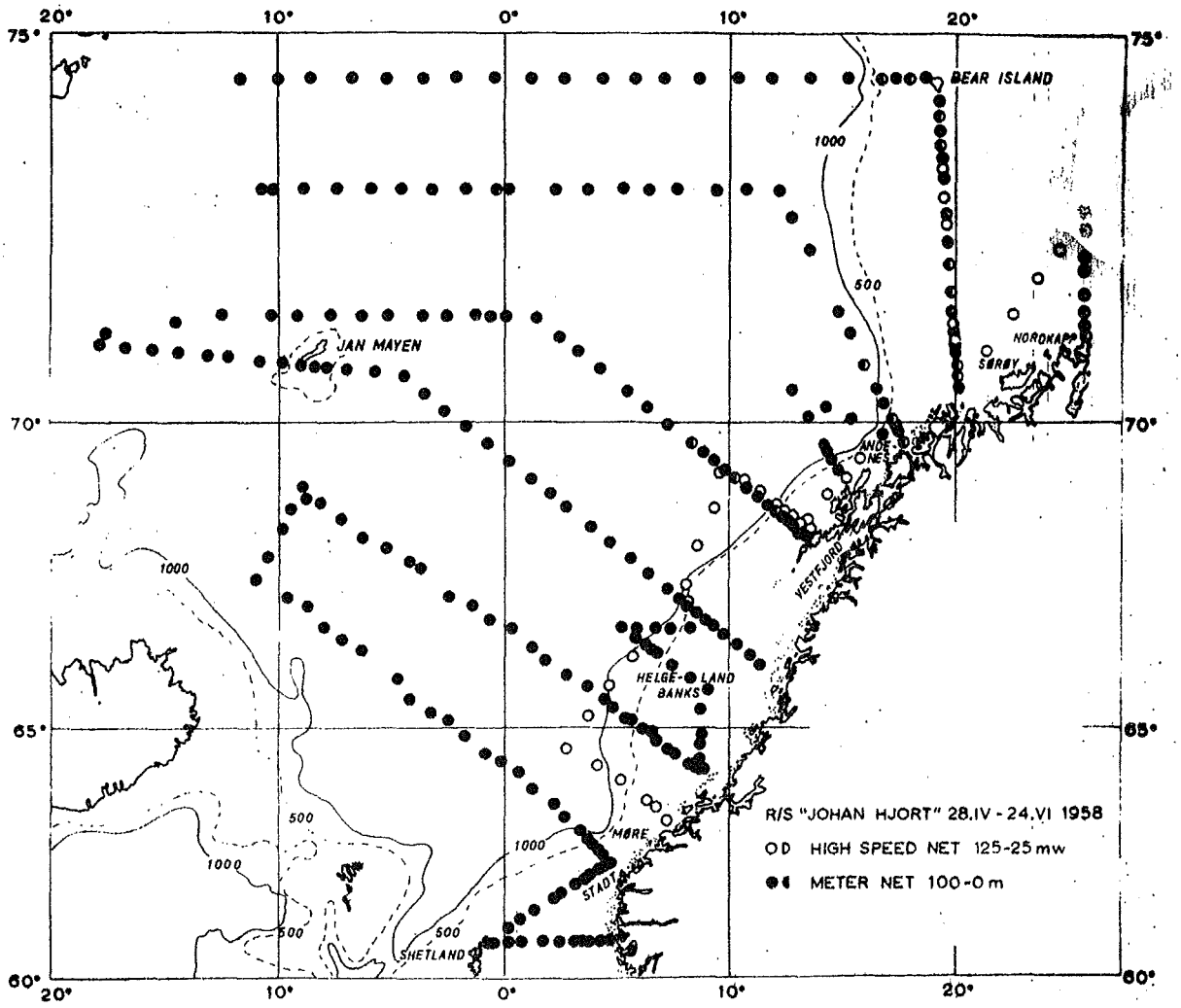

Fig. 2. Plankton stations in the Norwegian Sea April-June 1958.

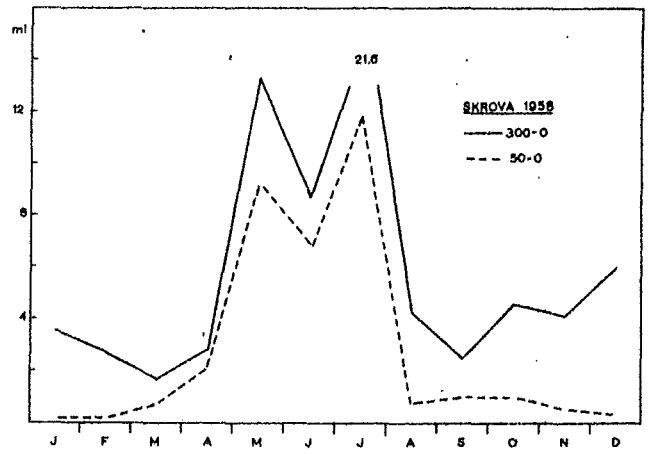

Fig. 3. Variations in plankton volume at Skrova. Monthly means. Nansen net hauls.

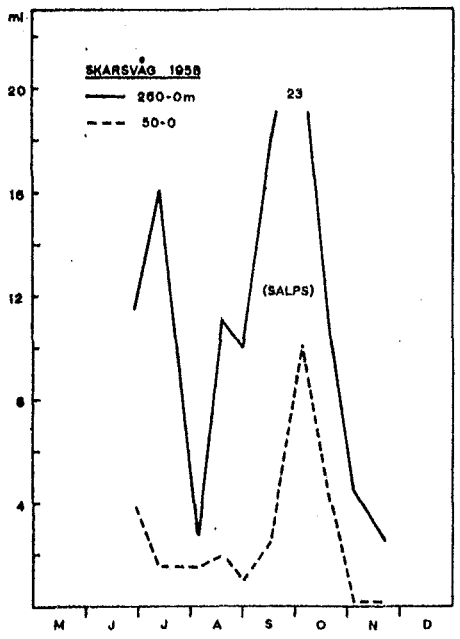

Fig. 4. Variations in plankton volume at Skarsvåg, June-November 1958. Nansen net hauls

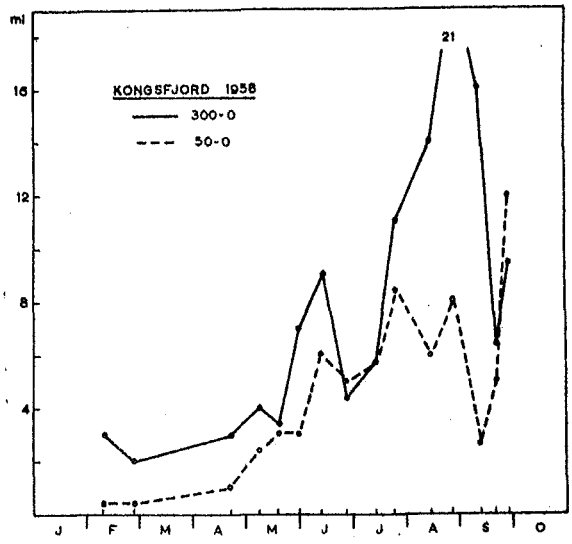

Fig. 5. Variations in plankton volume at Kongsfjord, February-October 1958. Small Nansen net, "8/50", and double figures.

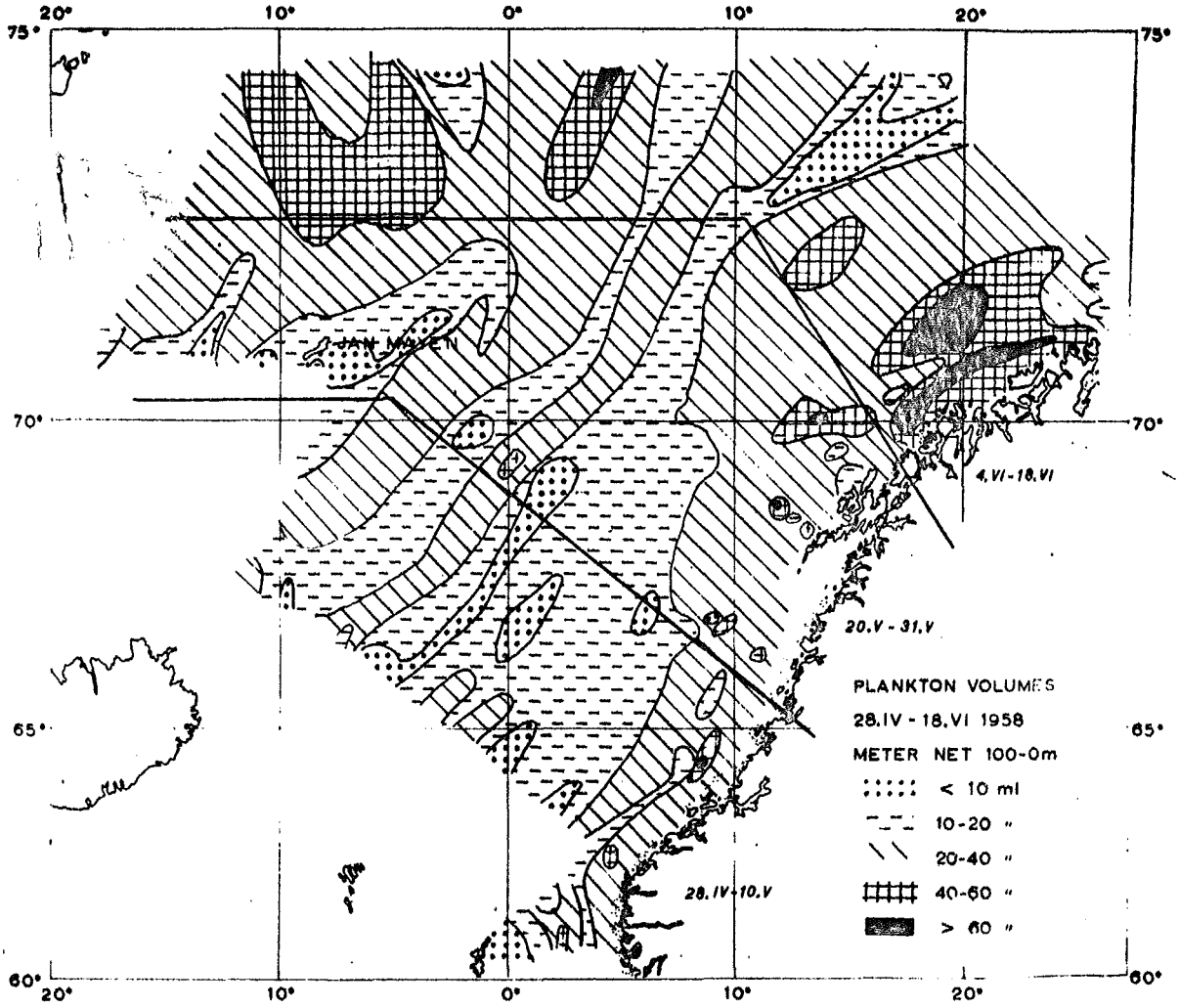

Fig. 6. The quantitative distribution of zooplankton, April-June 1959, one metre egg net, 100-0 m.

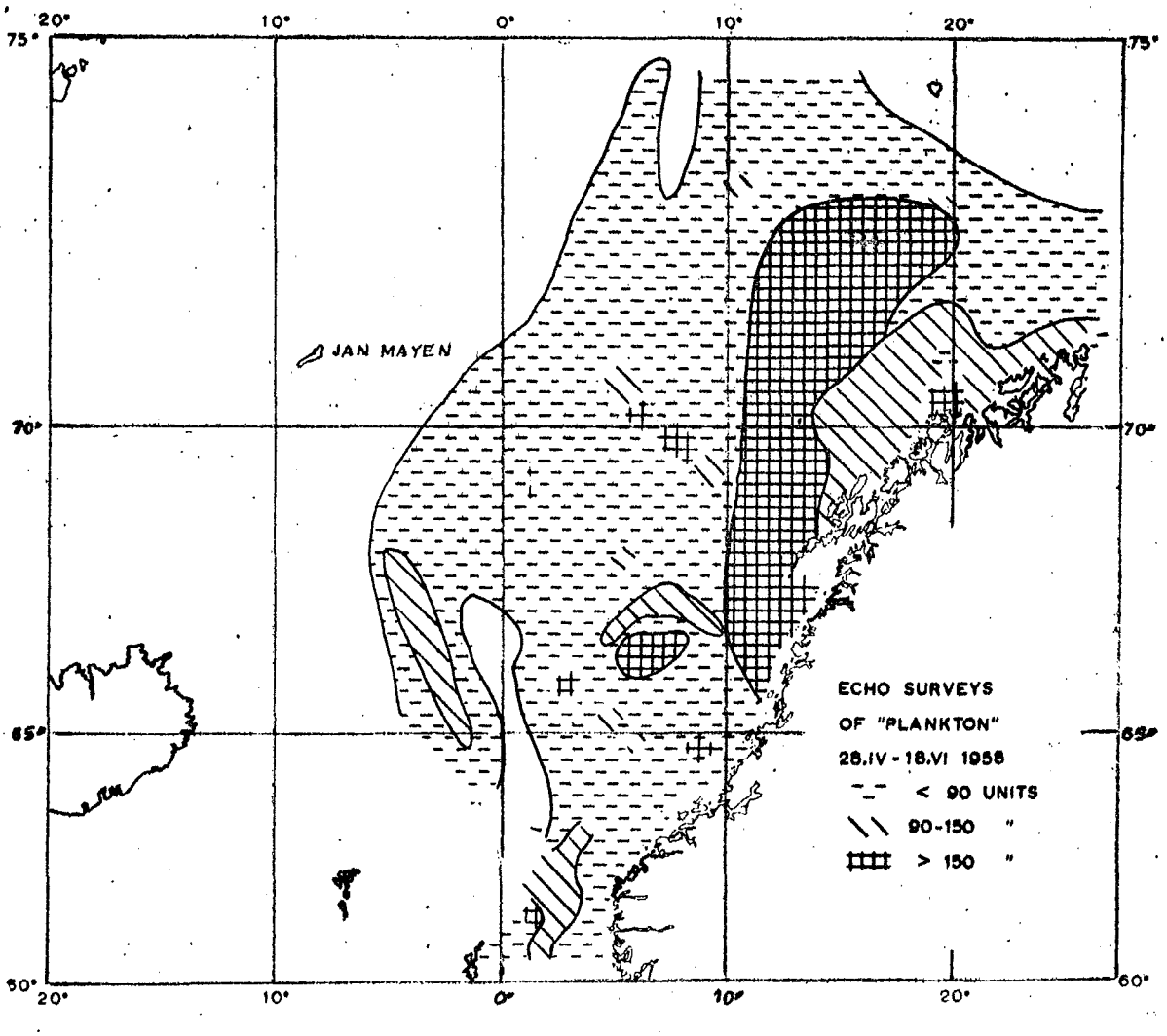

Fig. 7. Echo surveys of "plankton" April-June 1958.

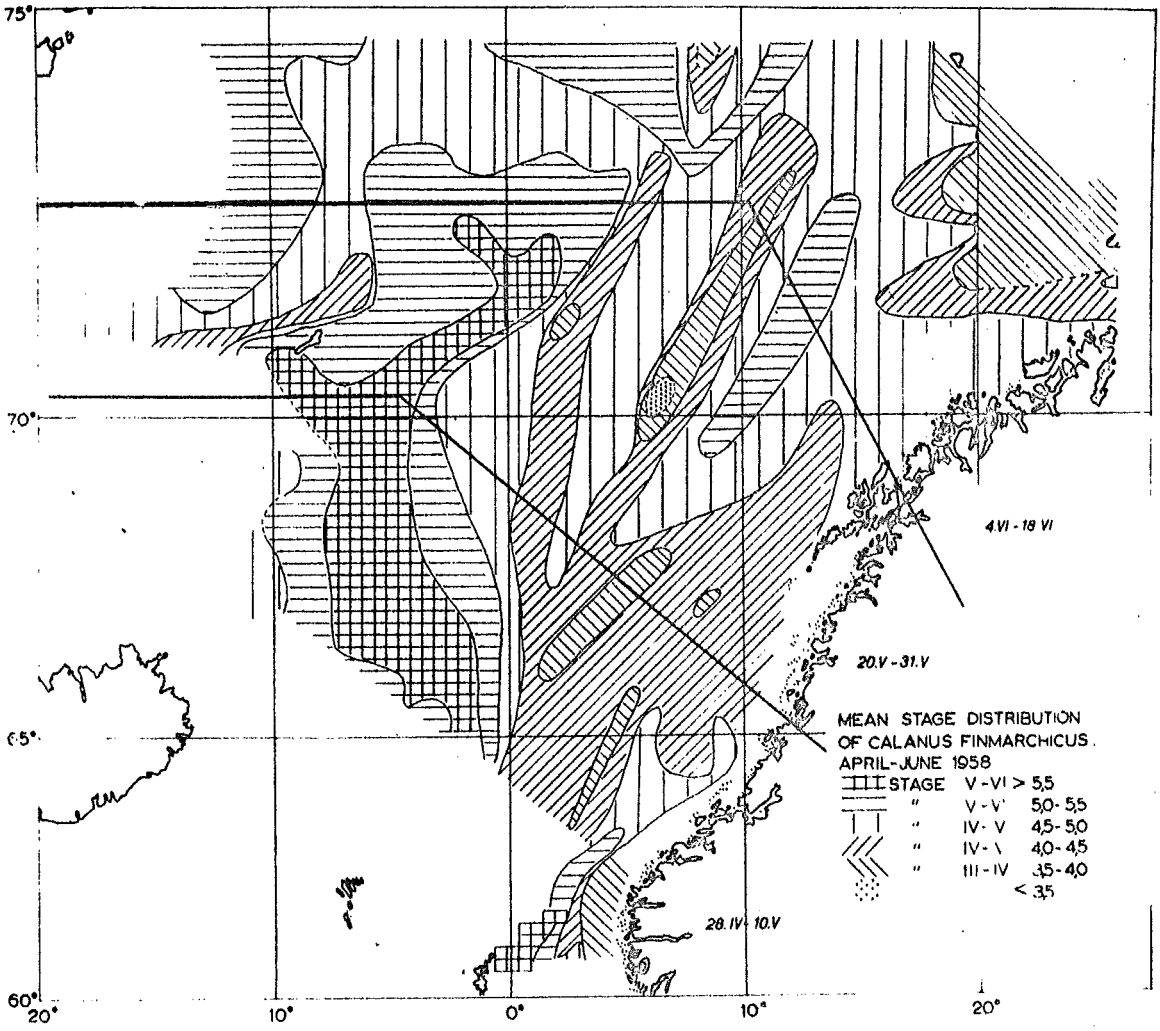

Fig. 8. The mean stage distribution of Calanus finmarchicus April-June 1958.

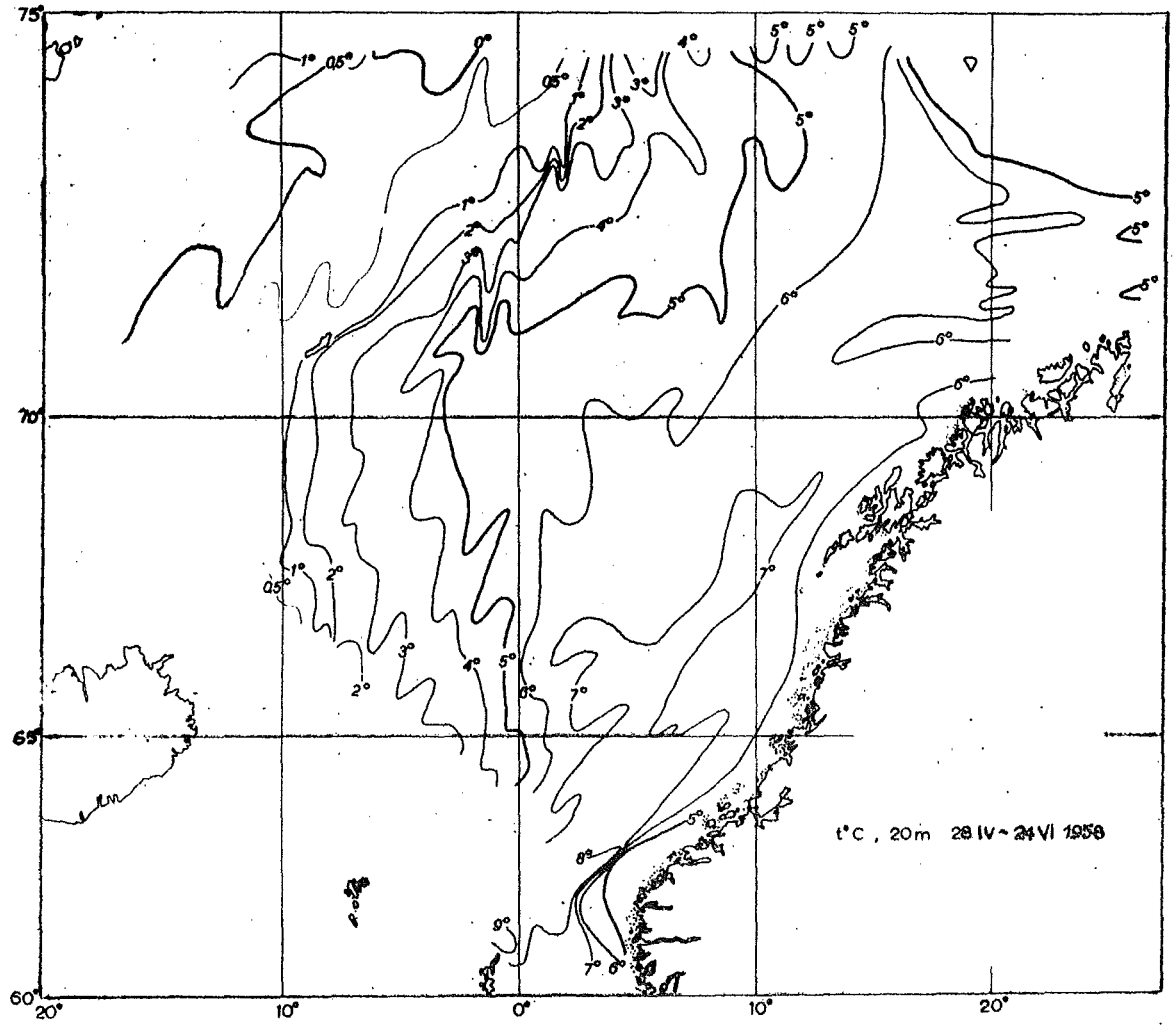

Fig. 9. The isotherms in 20 m, April-June 1958.

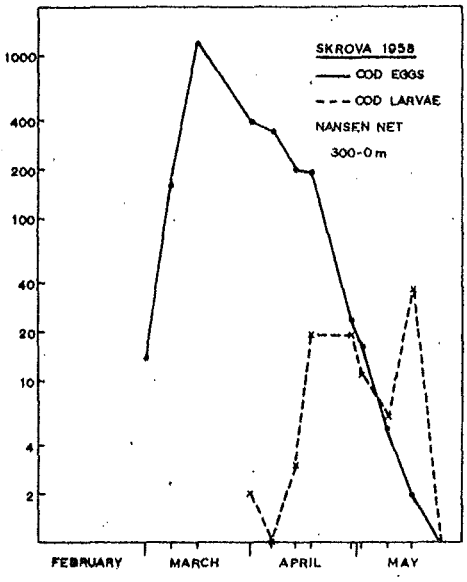

Fig. 10. Number of cod eggs, and larvae in vertical Nansen net hauls at Skrova February-May 1958.

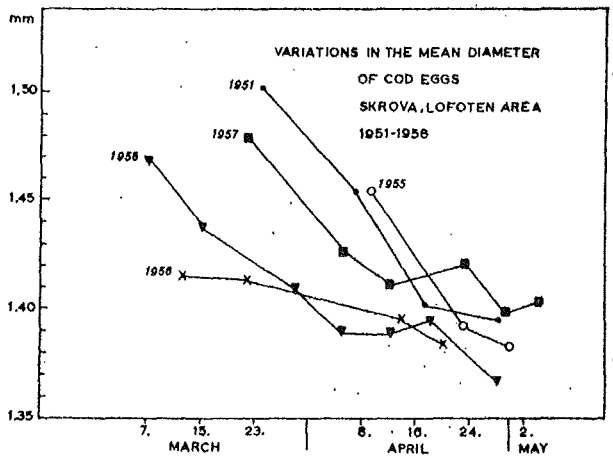

Fig. 11. Variations in the mean diameter of cod eggs at Skrova during the period March-May in various years.

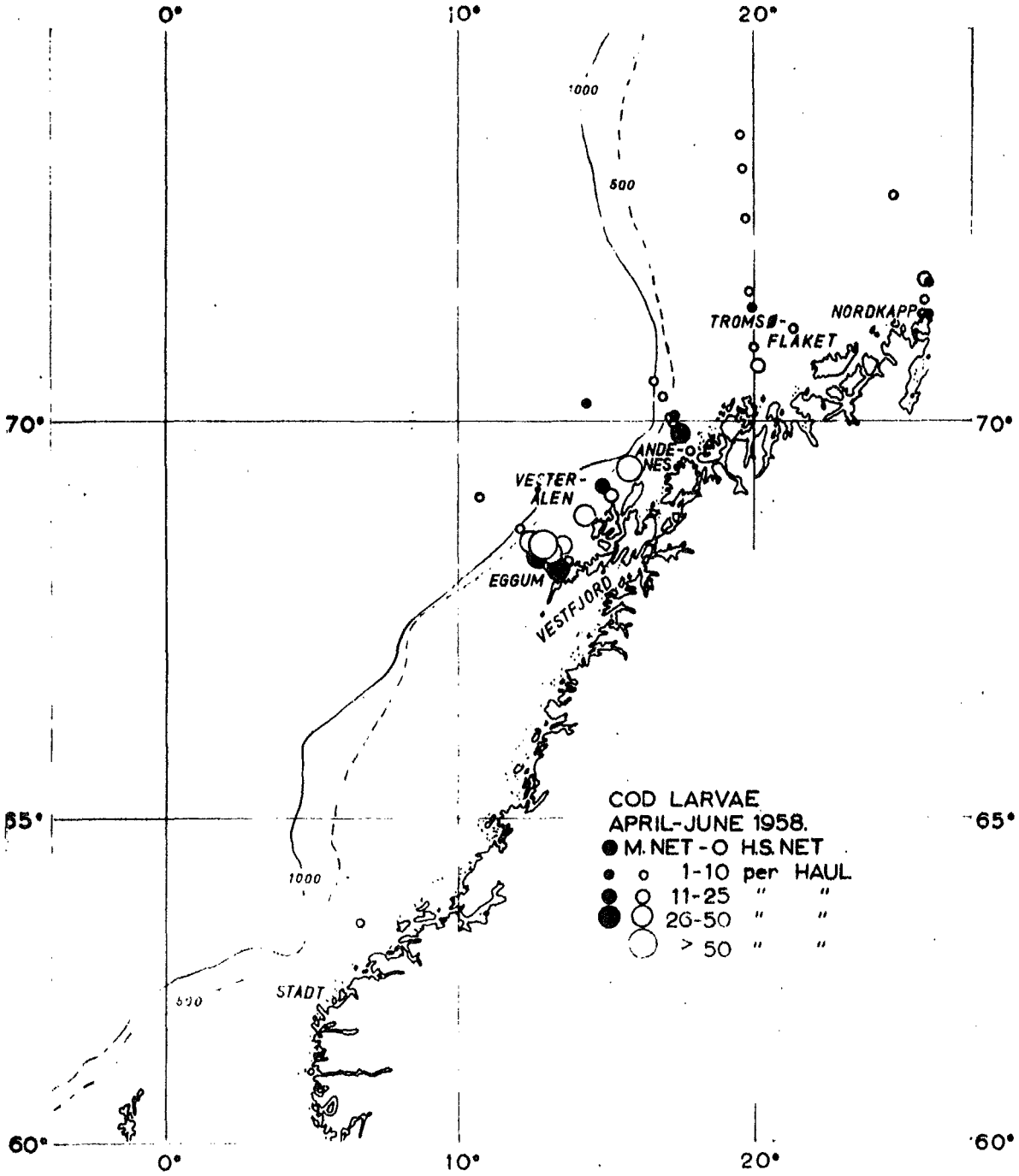

Fig. 12. The quantitative distribution of cod larvae April-June 1958.

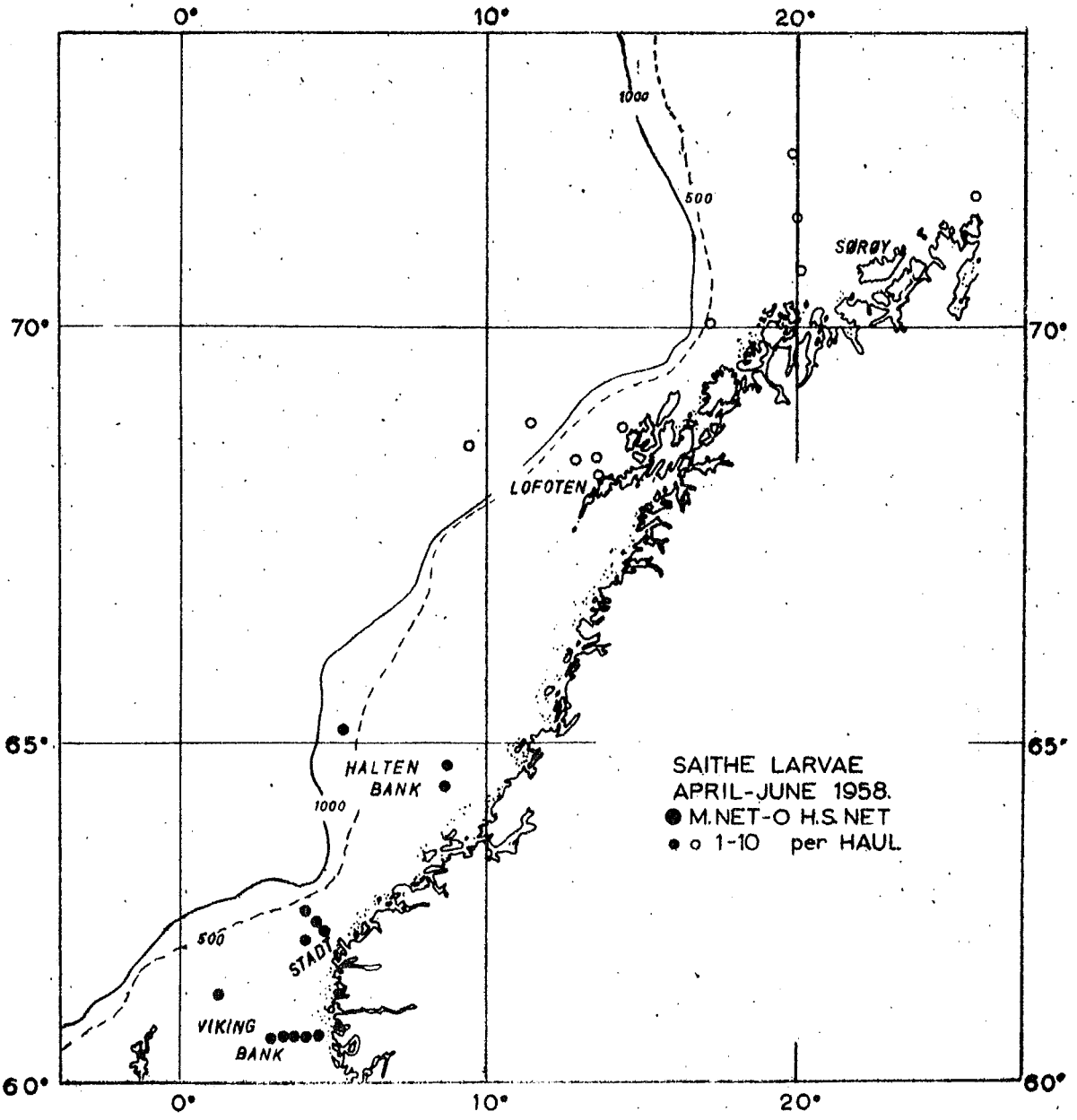

Fig. 14. The quantitative distribution of saithe larvae April-June 1958.

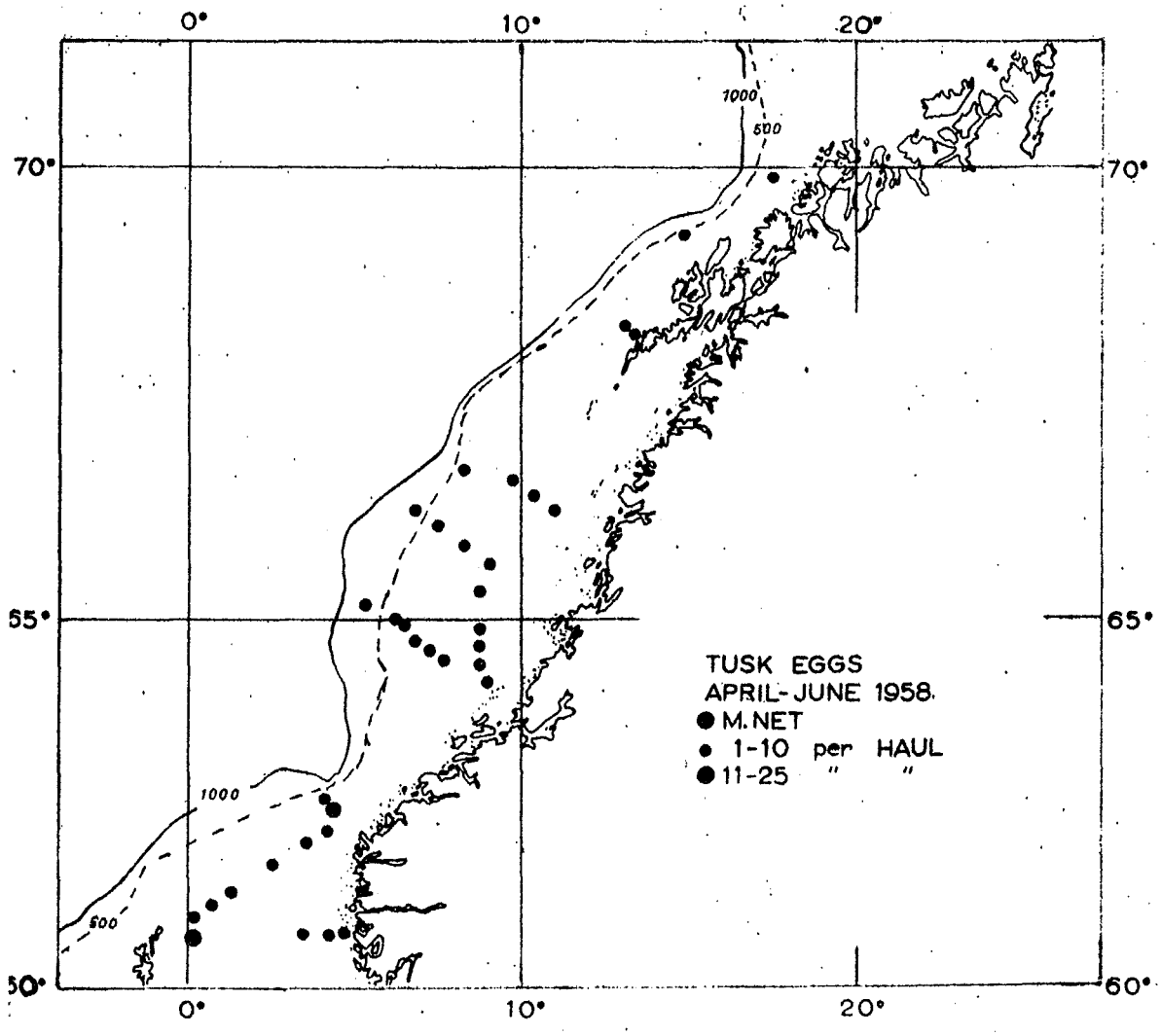

Fig. 15. The quantitative distribution of tusk eggs April-June 1958.

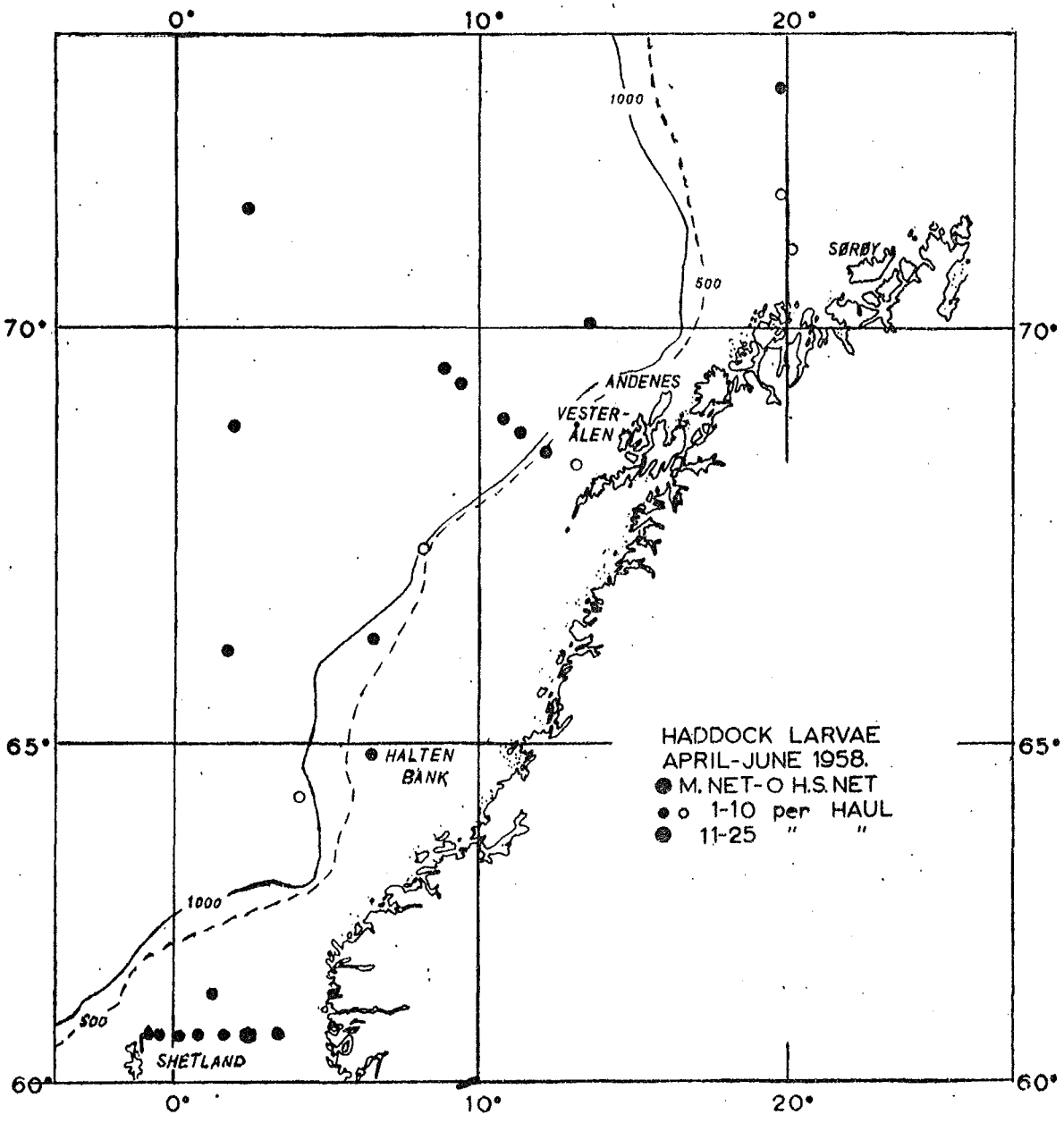

Fig. 13. The quantitative distribution of haddock larvae April-June 1958.

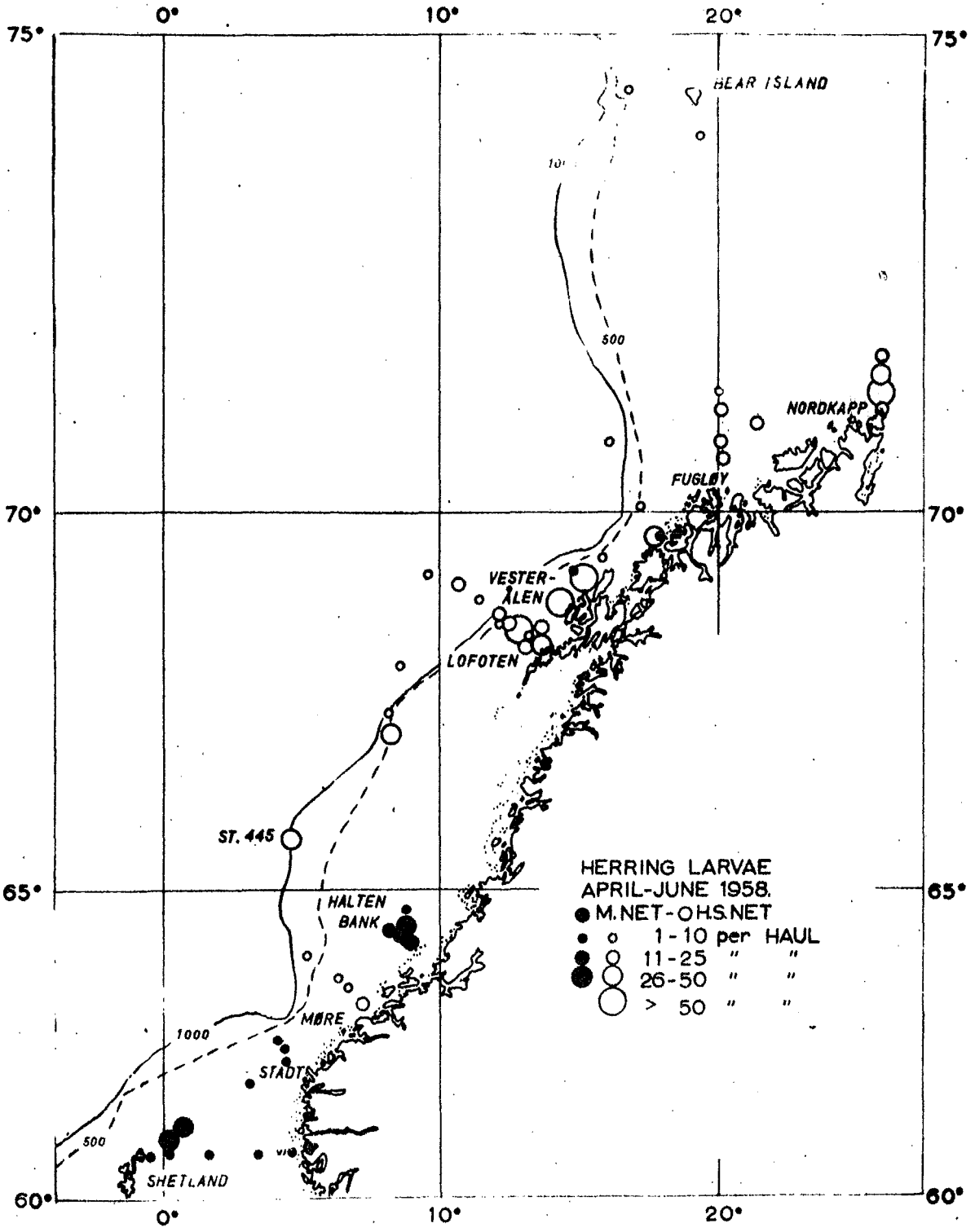

Fig. 16. The quantitative distribution of herring larvae April-June 1958.

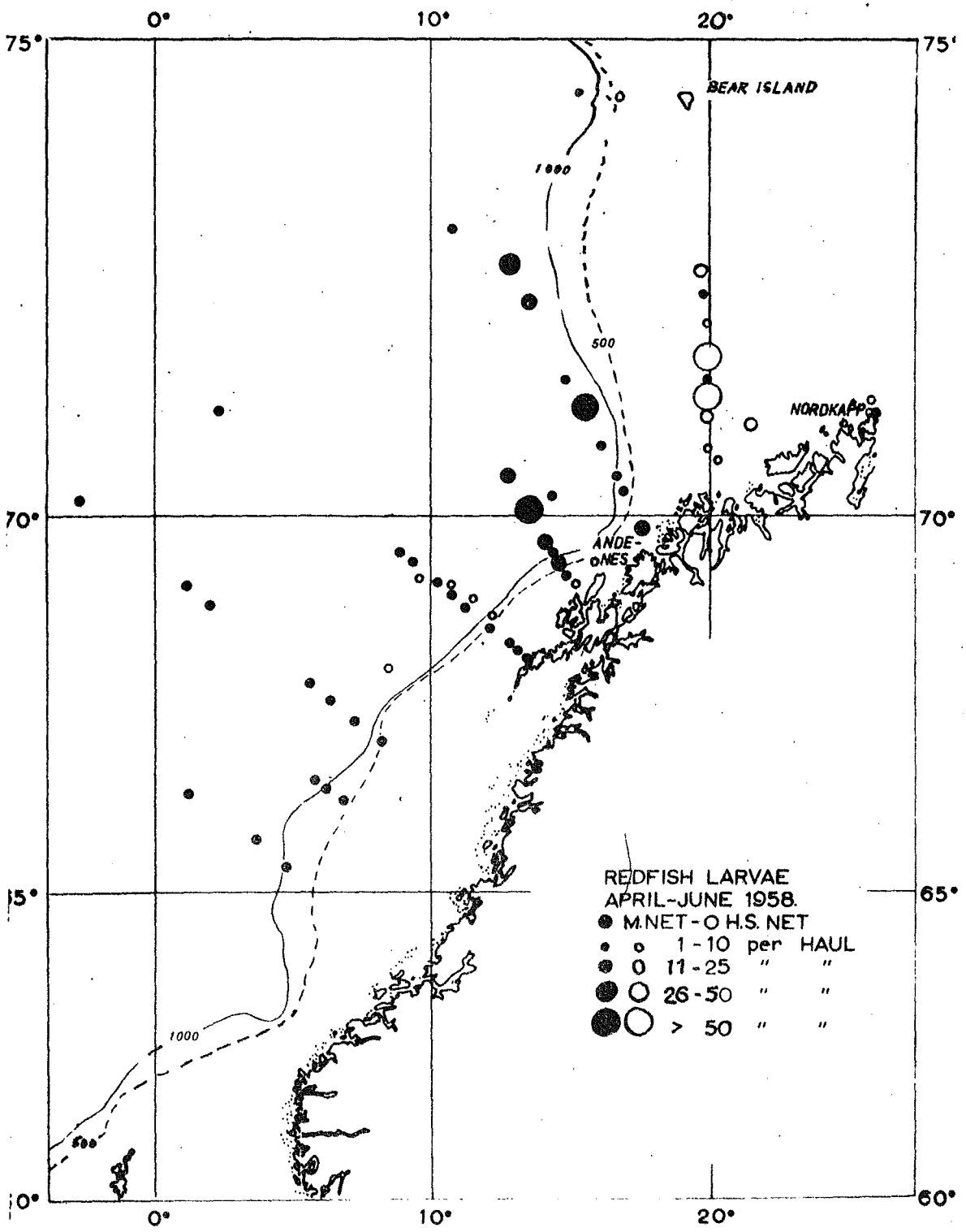

Fig. 17. The quantitative distribution of redfish larvae April-June 1958.